SIAM Conference on Computational Science and Engineering

Short Course on the ACTS Collection:

Robust and High Performance Libraries for Computational Sciences

TAU

(Performance Analysis and Tuning)

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TAU Performance Systems Goals

- Multi-level performance instrumentation
  - Multi-language automatic source instrumentation
- Flexible and configurable performance measurement
- Widely-ported parallel performance profiling system
  - Computer system architectures and operating systems
  - Different programming languages and compilers
- Support for multiple parallel programming paradigms
  - Multi-threading, message passing, mixed-mode, hybrid
- Support for performance mapping
- Support for object-oriented and generic programming
- Integration in complex software systems and applications

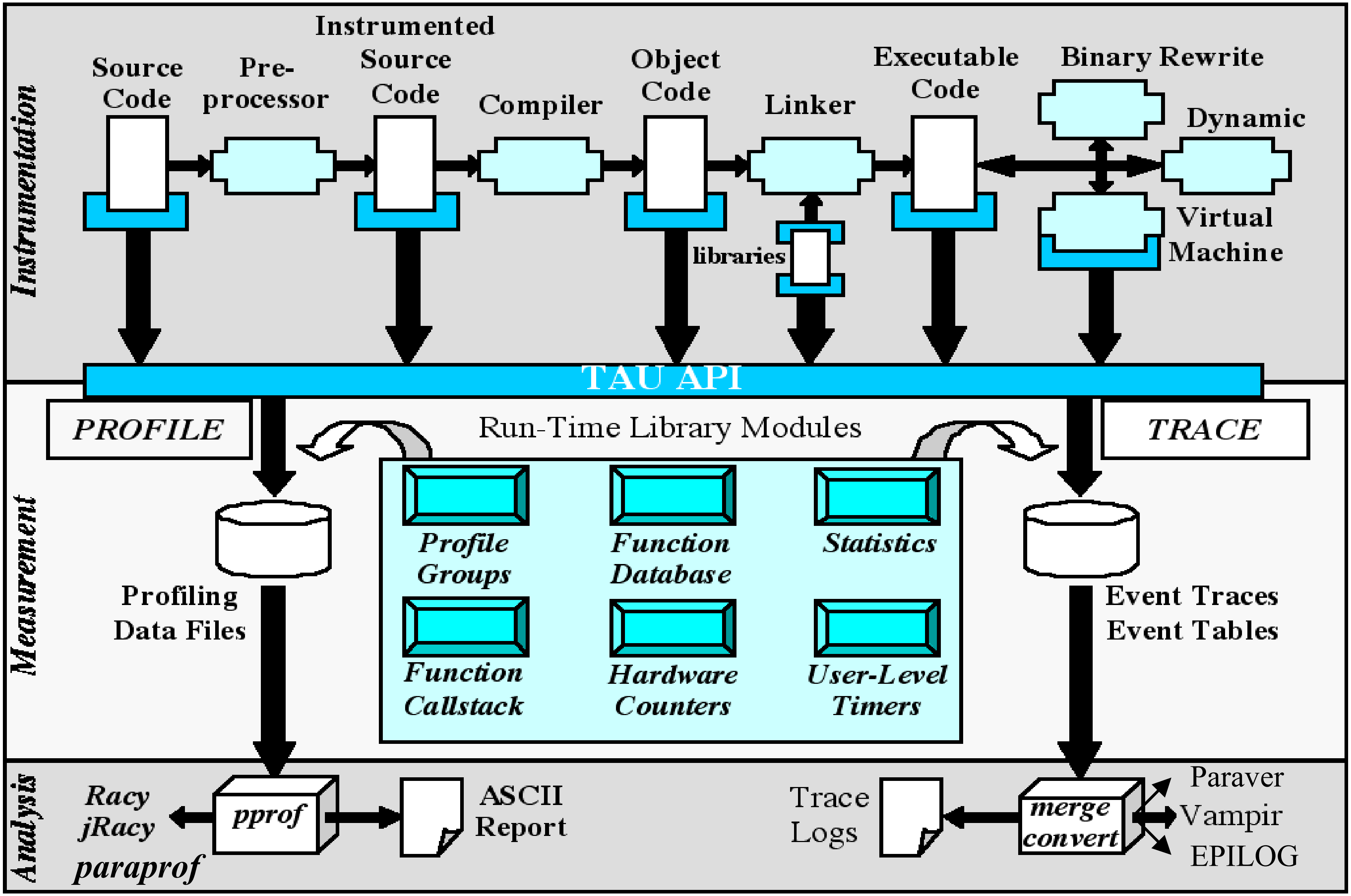
Definitions – Profiling

- Profiling
  - Recording of summary information during execution
    - inclusive, exclusive time, # calls, hardware statistics, …
  - Reflects performance behavior of program entities
    - functions, loops, basic blocks
    - user-defined “semantic” entities
  - Very good for low-cost performance assessment
  - Helps to expose performance bottlenecks and hotspots
  - Implemented through
    - sampling: periodic OS interrupts or hardware counter traps
    - instrumentation: direct insertion of measurement code

Definitions – Tracing

- Tracing
  - Recording of information about significant points (events) during program execution
    - entering/exiting code region (function, loop, block, …)
    - thread/process interactions (e.g., send/receive message)
  - Save information in event record
    - timestamp
    - CPU identifier, thread identifier
    - Event type and event-specific information
  - Event trace is a time-sequenced stream of event records
  - Can be used to reconstruct dynamic program behavior
  - Typically requires code instrumentation

TAU Performance System Architecture



TAU Instrumentation Approach

- Support for standard program events
  - Routines
  - Classes and templates
  - Statement-level blocks
- Support for user-defined events
  - Begin/End events (“user-defined timers”)
  - Atomic events (e.g., size of memory allocated/freed)
  - Selection of event statistics
- Support definition of “semantic” entities for mapping
- Support for event groups
- Instrumentation optimization (eliminate instrumentation in lightweight routines)

TAU Instrumentation

- Flexible instrumentation mechanisms at multiple levels
  - Source code
    - manual (TAU API, TAU Component API)
    - automatic
      - C, C++, F77/90/95 (Program Database Toolkit (*PDT*))
      - OpenMP (directive rewriting with *Opari, POMP spec)*
  - Object code
    - pre-instrumented libraries (e.g., MPI using *PMPI*)
    - statically-linked and dynamically-linked
  - Executable code
    - dynamic instrumentation (pre-execution) (*DynInstAPI*)
    - virtual machine instrumentation (e.g., Java using *JVMPI*)
  - Proxy Components

Using TAU

- Install TAU

  ```
  % configure ; make clean install
  ```

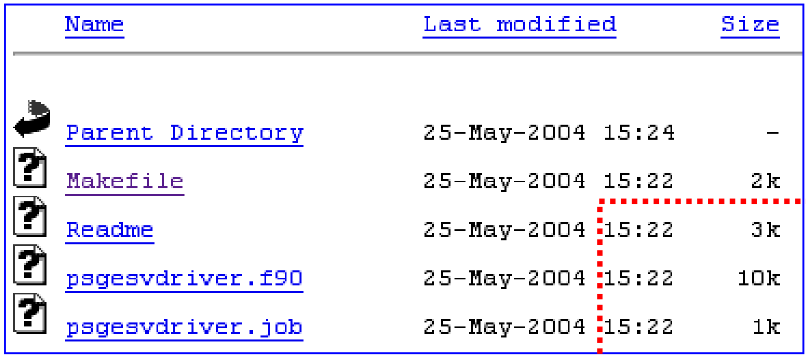
- Instrument application
  - TAU Profiling API
- Typically modify application makefile
  - include TAU’s stub makefile, modify variables
- Set environment variables
  - directory where profiles/traces are to be stored
  - name of merged trace file, retain intermediate trace files, etc.
- Execute application

  ```
  % mpirun –np <procs> a.out;
  ```

- Analyze performance data
  - paraprof, vampir, pprof, paraver …

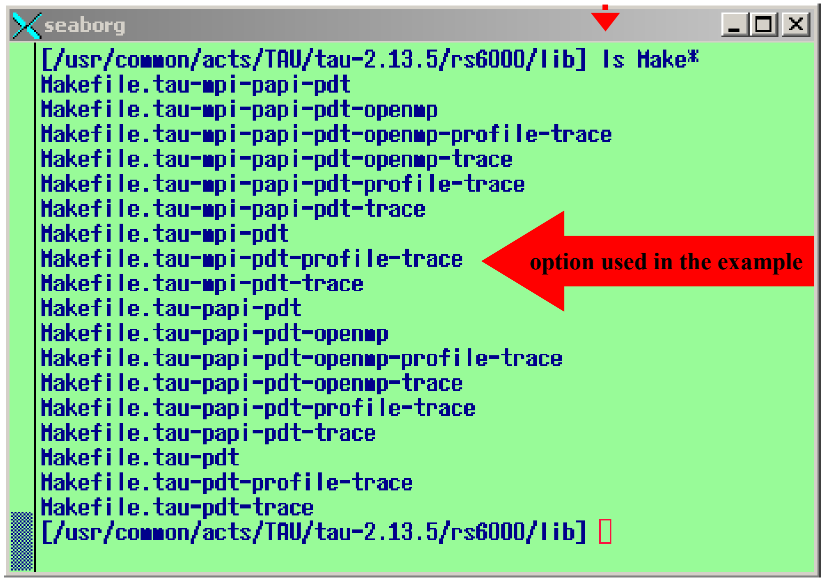
TAU: *Example 1* (1/4)

Index of *http://acts.nersc.gov/tau/programs/psgesv*



Name	Last modified	Size
Parent Directory	25-May-2004 15:24	-
Makefile	25-May-2004 15:22	2k
Readme	25-May-2004 15:22	3k
psgesvdriver.f90	25-May-2004 15:22	10k
psgesvdriver.job	25-May-2004 15:22	1k

Options currently installed:



```
[/usr/common/acts/TAU/tau-2.13.5/rs6000/lib] ls Make*
Makefile.tau-mpi-papi-pdt
Makefile.tau-mpi-papi-pdt-openmp
Makefile.tau-mpi-papi-pdt-openmp-profile-trace
Makefile.tau-mpi-papi-pdt-openmp-trace
Makefile.tau-mpi-papi-pdt-profile-trace
Makefile.tau-mpi-papi-pdt-trace
Makefile.tau-mpi-pdt
Makefile.tau-mpi-pdt-profile-trace
Makefile.tau-mpi-pdt-trace
Makefile.tau-papi-pdt
Makefile.tau-papi-pdt-openmp
Makefile.tau-papi-pdt-openmp-profile-trace
Makefile.tau-papi-pdt-openmp-trace
Makefile.tau-papi-pdt-profile-trace
Makefile.tau-papi-pdt-trace
Makefile.tau-pdt
Makefile.tau-pdt-profile-trace
Makefile.tau-pdt-trace
[/usr/common/acts/TAU/tau-2.13.5/rs6000/lib]
```

option used in the example

```
#*************************************************************************
#*                                                                       *
#* This makefile shows how to use TAU to automatically instrument and   *
#* compile a simple Fortran program that calls the ScaLAPACK routine    *
#* PSGESV to solve a system of linear equations. It requires the        *
#* modules "tau" and "scalapack", as well as "gmake"                    *
#*                                                                       *
#*************************************************************************
```

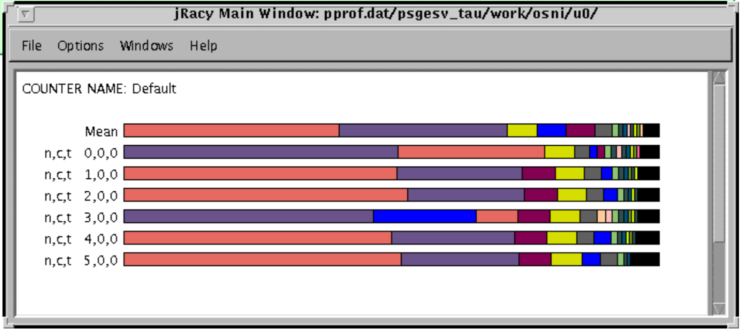
```
# The following defines the TAU macros
# For other options see $(TAUROOTDIR)/rs6000/lib
include $(TAUROOTDIR)/rs6000/lib/Makefile.tau-mpi-pdt-profile-trace

# Comment the following line to disable TAU
USE_TAU = 1

F90                = $(TAU_F90)
LINKER             = $(TAU_LINKER)
PDTF90PARSE        = $(PDTDIR)/$(PDTARCHDIR)/bin/f90parse
TAUINSTR           = $(TAUROOTDIR)/$(CONFIG_ARCH)/bin/tau_instrumentor
FFLAGS             = $(TAU_MPI_INCLUDE) $(TAU_F90_SUFFIX)
LIBS               = $(TAU_MPI_FLIBS) $(TAU_LIBS) $(TAU_FORTRANLIBS)
LDFLAGS            = -brtl -binitfini:poe_remote_main
```

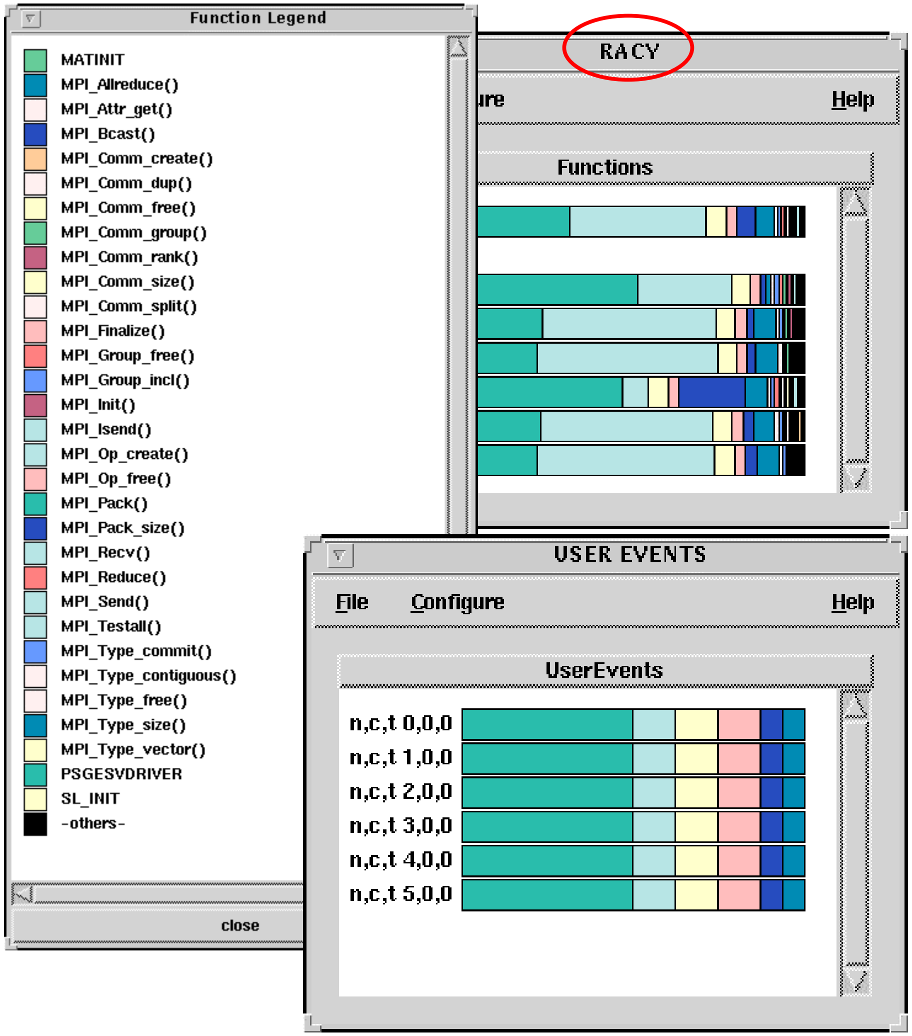
```
ifdef USE_TAU
# Rule used for automatic instrumentation
COMP_RULE = $(PDTF90PARSE) $< $(FFLAGS); \
        $(TAUINSTR) $*.pdb $< -o $*.inst.f90 ; \
        $(F90) $(FFLAGS) -c $*.inst.f90 -o $@ ; \
        rm -f $*.pdb ;
else
# Disable TAU instrumentation
TAU_DEFS =
# Don't use TAU MPI wrapper library
TAU_MPI_LIBS = -L/usr/local/lib -lmpich -lgm
TAU_LIBS =
TAU_WRAPPER_LIB =
TAU_INCLUDE =
COMP_RULE = $(F90) $(FFLAGS) -c $< -o $@ ;
LIBS = $(TAU_MPI_LIBS)
LINKER = $(F90)
endif
```

TAU: *Example 1* (2/4)

psgesvdriver.int.f90

```
 PROGRAM PSGESVDRIVER
!
!     Example Program solving Ax=b via ScaLAPACK routine PSGESV
!
!     .. Parameters ..

!**** a bunch of things omitted for the sake of space ****

!     .. Executable Statements ..
!
!     INITIALIZE THE PROCESS GRID
!
      integer profiler(2)
      save profiler

      call TAU_PROFILE_INIT()
      call TAU_PROFILE_TIMER(profiler,'PSGESVDRIVER')
      call TAU_PROFILE_START(profiler)
      CALL SL_INIT( ICTXT, NPROW, NPCOL )
      CALL BLACS_GRIDINFO( ICTXT, NPROW, NPCOL, MYROW, MYCOL )

!**** a bunch of things omitted for the sake of space ****

      CALL PSGESV( N, NRHS, A, IA, JA, DESCA, IPIV, B, IB, JB, DESCB, &
                   INFO )

!**** a bunch of things omitted for the sake of space ****

      call TAU_PROFILE_STOP(profiler)
      STOP
      END
```

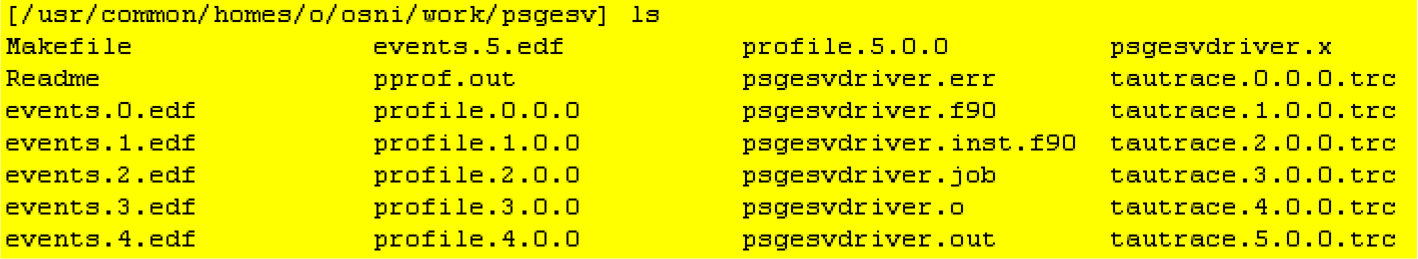




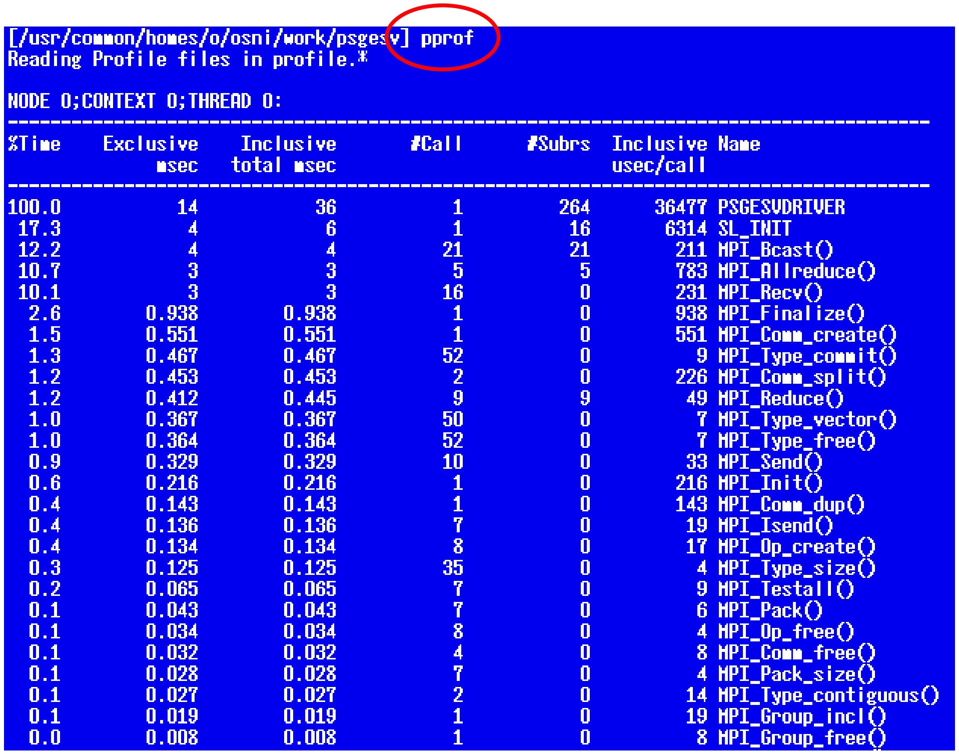
🟩 MATINIT
🟦 MPI_Allreduce()
⬜ MPI_Attr_get()
🟦 MPI_Bcast()
🟧 MPI_Comm_create()
⬜ MPI_Comm_dup()
🟨 MPI_Comm_free()
🟩 MPI_Comm_group()
🟥 MPI_Comm_rank()
🟨 MPI_Comm_size()
⬜ MPI_Comm_split()
🟥 MPI_Finalize()
🟥 MPI_Group_free()
🟦 MPI_Group_incl()
🟥 MPI_Init()
🟦 MPI_Isend()
🟦 MPI_Op_create()
🟥 MPI_Op_free()
🟩 MPI_Pack()
🟦 MPI_Pack_size()
🟦 MPI_Recv()
🟥 MPI_Reduce()
🟦 MPI_Send()
🟦 MPI_Testall()
🟦 MPI_Type_commit()
⬜ MPI_Type_contiguous()
⬜ MPI_Type_free()
🟦 MPI_Type_size()
🟨 MPI_Type_vector()
🟩 PSGESVDRIVER
🟨 SL_INIT
⬛ -others-

NB. ScaLAPACK routines have not been instrumented and therefore are not shown in the charts.

TAU: *Example 1* (3/4)



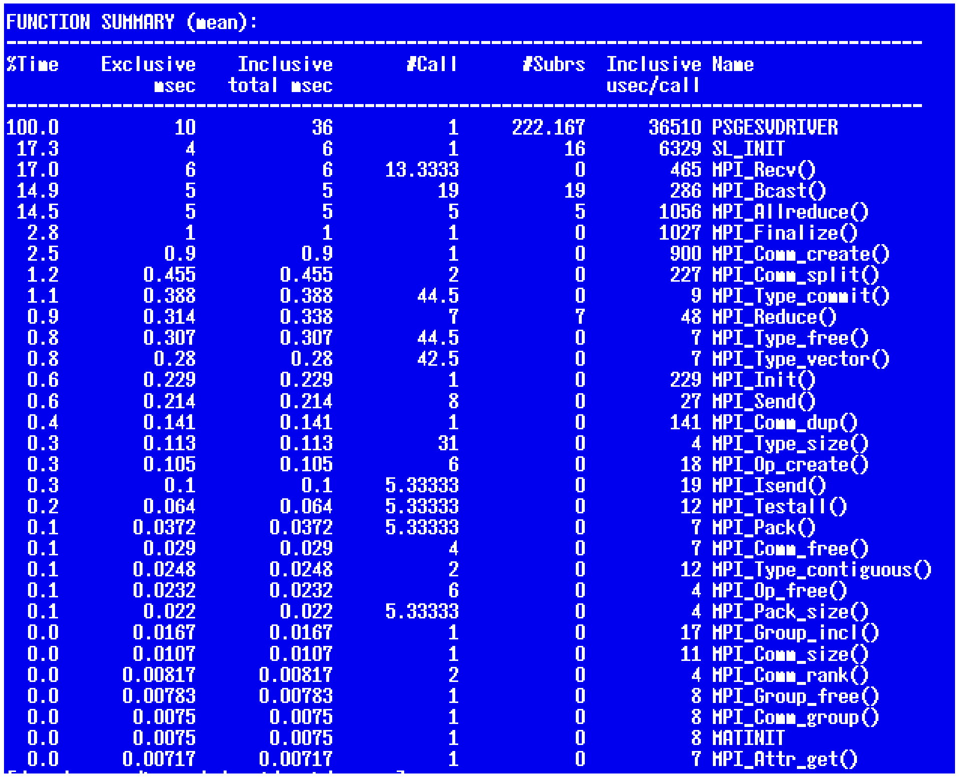
```
[/usr/common/homes/o/osni/work/psgesv] ls
Makefile          events.5.edf      profile.5.0.0           psgesvdriver.x
Readme            pprof.out         psgesvdriver.err        tautrace.0.0.0.trc
events.0.edf      profile.0.0.0     psgesvdriver.f90        tautrace.1.0.0.trc
events.1.edf      profile.1.0.0     psgesvdriver.inst.f90   tautrace.2.0.0.trc
events.2.edf      profile.2.0.0     psgesvdriver.job        tautrace.3.0.0.trc
events.3.edf      profile.3.0.0     psgesvdriver.o          tautrace.4.0.0.trc
events.4.edf      profile.4.0.0     psgesvdriver.out        tautrace.5.0.0.trc
```



```
[/usr/common/homes/o/osni/work/psgesv] pprof
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0           14           36           1         264      36477 PSGESVDRIVER
 17.3            4            6           1          16       6314 SL_INIT
 12.2            4            4          21          21        211 MPI_Bcast()
 10.7            3            3           5           5        783 MPI_Allreduce()
 10.1            3            3          16           0        231 MPI_Recv()
  2.6        0.938        0.938           1           0        938 MPI_Finalize()
  1.5        0.551        0.551           1           0        551 MPI_Comm_create()
  1.3        0.467        0.467          52           0          9 MPI_Type_commit()
  1.2        0.453        0.453           2           0        226 MPI_Comm_split()
  1.2        0.412        0.445           9           9         49 MPI_Reduce()
  1.0        0.367        0.367          50           0          7 MPI_Type_vector()
  1.0        0.364        0.364          52           0          7 MPI_Type_free()
  0.9        0.329        0.329          10           0         33 MPI_Send()
  0.6        0.216        0.216           1           0        216 MPI_Init()
  0.4        0.143        0.143           1           0        143 MPI_Comm_dup()
  0.4        0.136        0.136           7           0         19 MPI_Isend()
  0.4        0.134        0.134           8           0         17 MPI_Op_create()
  0.3        0.125        0.125          35           0          4 MPI_Type_size()
  0.2        0.065        0.065           7           0          9 MPI_Testall()
  0.1        0.043        0.043           7           0          6 MPI_Pack()
  0.1        0.034        0.034           8           0          4 MPI_Op_free()
  0.1        0.032        0.032           4           0          8 MPI_Comm_free()
  0.1        0.028        0.028           7           0          4 MPI_Pack_size()
  0.1        0.027        0.027           2           0         14 MPI_Type_contiguous()
  0.1        0.019        0.019           1           0         19 MPI_Group_incl()
  0.0        0.008        0.008           1           0          8 MPI_Group_free()
```

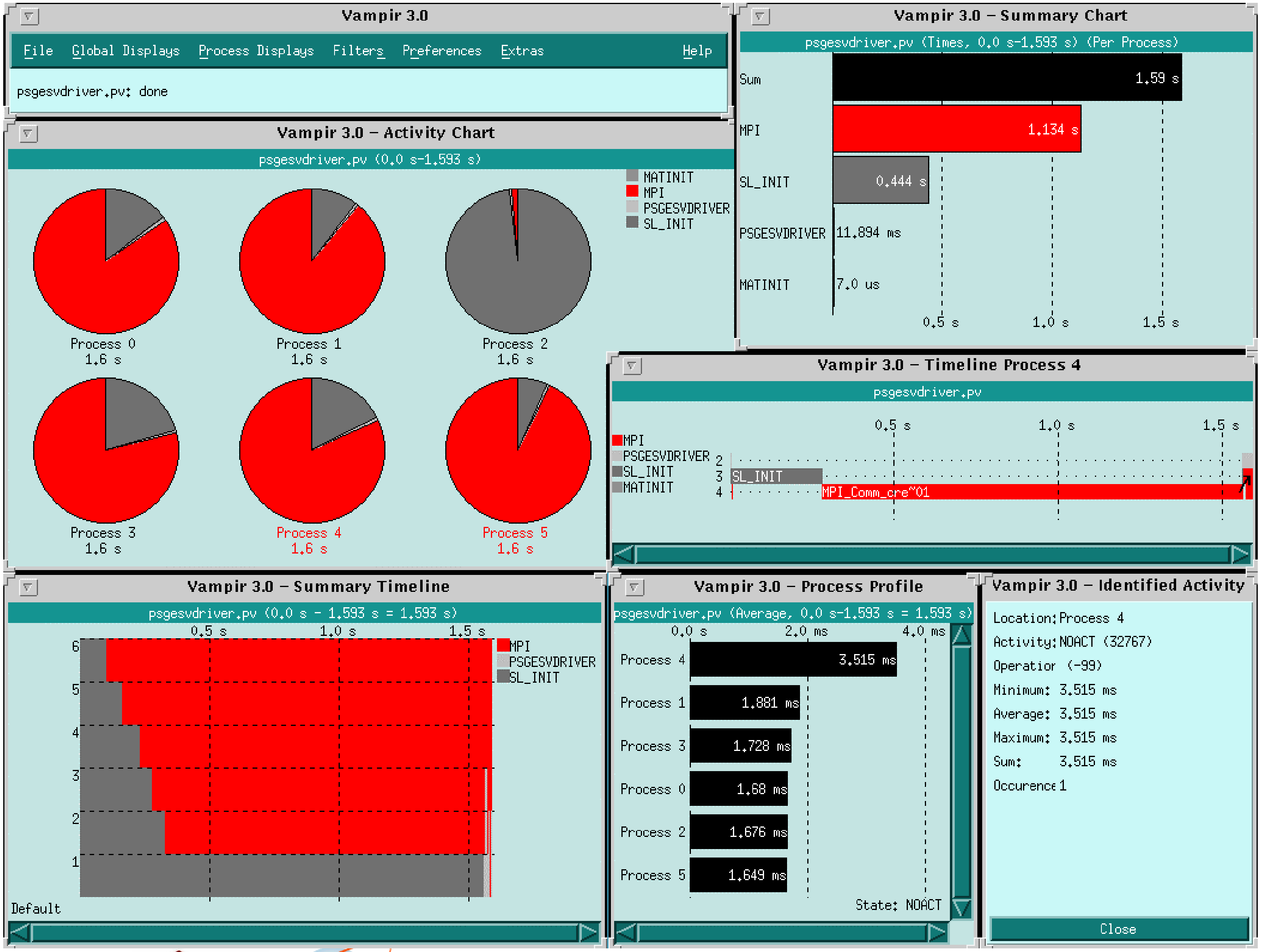
⋮

⋮



```
FUNCTION SUMMARY (mean):
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0           10           36           1     222.167      36510 PSGESVDRIVER
 17.3            4            6           1          16       6329 SL_INIT
 17.0            6            6     13.3333           0        465 MPI_Recv()
 14.9            5            5          19          19        286 MPI_Bcast()
 14.5            5            5           5           5       1056 MPI_Allreduce()
  2.8            1            1           1           0       1027 MPI_Finalize()
  2.5          0.9          0.9           1           0        900 MPI_Comm_create()
  1.2        0.455        0.455           2           0        227 MPI_Comm_split()
  1.1        0.388        0.388        44.5           0          9 MPI_Type_commit()
  0.9        0.314        0.338           7           7         48 MPI_Reduce()
  0.8        0.307        0.307        44.5           0          7 MPI_Type_free()
  0.8         0.28         0.28        42.5           0          7 MPI_Type_vector()
  0.6        0.229        0.229           1           0        229 MPI_Init()
  0.6        0.214        0.214           8           0         27 MPI_Send()
  0.4        0.141        0.141           1           0        141 MPI_Comm_dup()
  0.3        0.113        0.113          31           0          4 MPI_Type_size()
  0.3        0.105        0.105           6           0         18 MPI_Op_create()
  0.3          0.1          0.1     5.33333           0         19 MPI_Isend()
  0.2        0.064        0.064     5.33333           0         12 MPI_Testall()
  0.1       0.0372       0.0372     5.33333           0          7 MPI_Pack()
  0.1        0.029        0.029           4           0          7 MPI_Comm_free()
  0.1       0.0248       0.0248           2           0         12 MPI_Type_contiguous()
  0.1       0.0232       0.0232           6           0          4 MPI_Op_free()
  0.1        0.022        0.022     5.33333           0          4 MPI_Pack_size()
  0.0       0.0167       0.0167           1           0         17 MPI_Group_incl()
  0.0       0.0107       0.0107           1           0         11 MPI_Comm_size()
  0.0      0.00817      0.00817           2           0          4 MPI_Comm_rank()
  0.0      0.00783      0.00783           1           0          8 MPI_Group_free()
  0.0       0.0075       0.0075           1           0          8 MPI_Comm_group()
  0.0       0.0075       0.0075           1           0          8 MATINIT
  0.0      0.00717      0.00717           1           0          7 MPI_Attr_get()
```

TAU: *Example 1* (4/4)

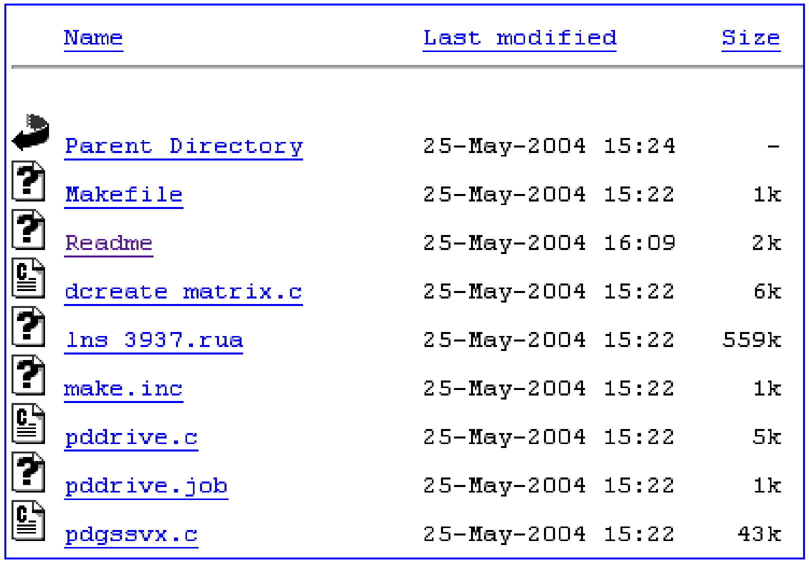


psgesvdriver.pv: done

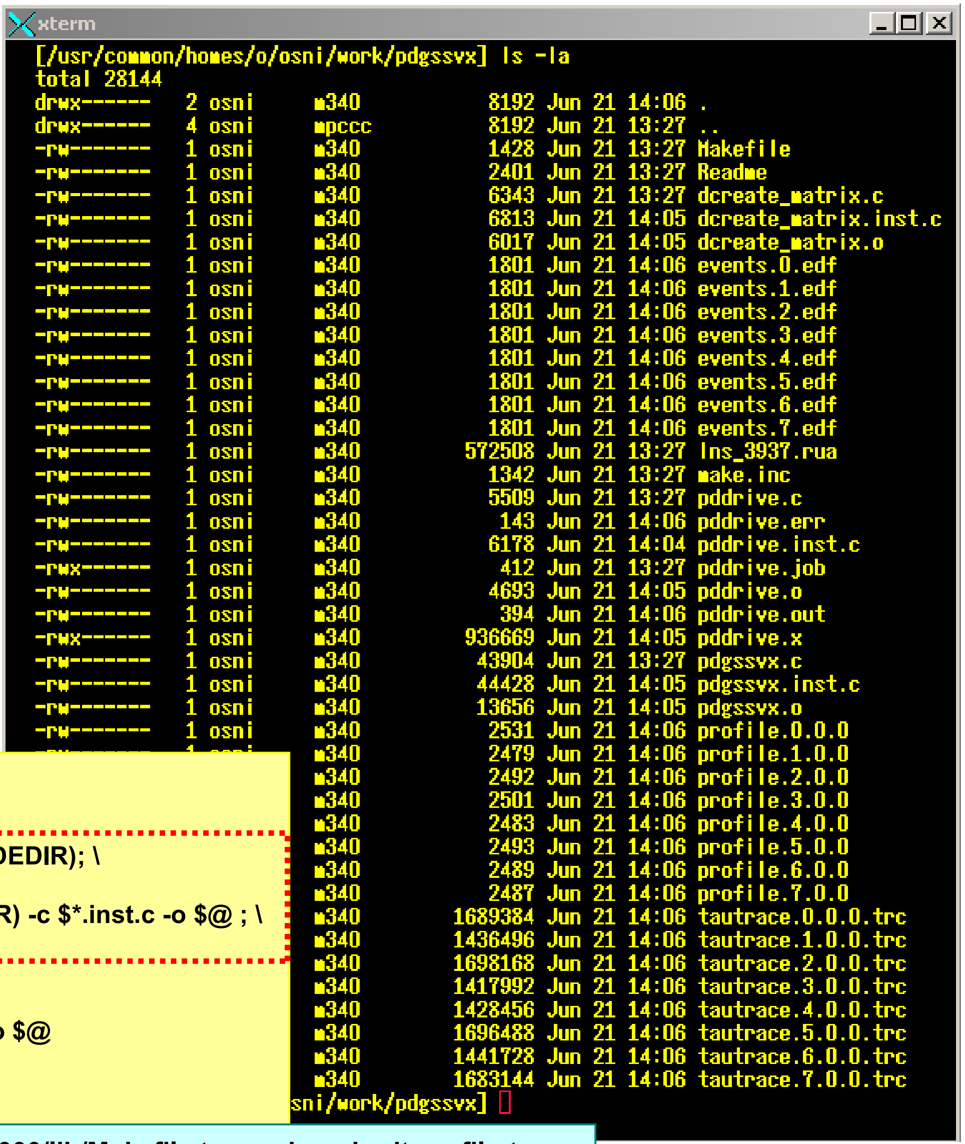
Location: Process 4
Activity: NOACT (32767)
Operation (-99)
Minimum: 3.515 ms
Average: 3.515 ms
Maximum: 3.515 ms
Sum: 3.515 ms
Occurence 1

TAU: *Example 2* (1/2)

Index of *http://acts.nersc.gov/tau/programs/pdgssvx*



Name	Last modified	Size
Parent Directory	25-May-2004 15:24	-
Makefile	25-May-2004 15:22	1k
Readme	25-May-2004 16:09	2k
dcreate_matrix.c	25-May-2004 15:22	6k
lns_3937.rua	25-May-2004 15:22	559k
make.inc	25-May-2004 15:22	1k
pddrive.c	25-May-2004 15:22	5k
pddrive.job	25-May-2004 15:22	1k
pdgssvx.c	25-May-2004 15:22	43k



```
[/usr/common/homes/o/osni/work/pdgssvx] ls -la
total 28144
drwx------   2 osni     m340            8192 Jun 21 14:06 .
drwx------   4 osni     mpccc           8192 Jun 21 13:27 ..
-rw-------   1 osni     m340            1428 Jun 21 13:27 Makefile
-rw-------   1 osni     m340            2401 Jun 21 13:27 Readme
-rw-------   1 osni     m340            6343 Jun 21 13:27 dcreate_matrix.c
-rw-------   1 osni     m340            6813 Jun 21 14:05 dcreate_matrix.inst.c
-rw-------   1 osni     m340            6017 Jun 21 14:05 dcreate_matrix.o
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.0.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.1.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.2.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.3.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.4.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.5.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.6.edf
-rw-------   1 osni     m340            1801 Jun 21 14:06 events.7.edf
-rw-------   1 osni     m340          572508 Jun 21 13:27 lns_3937.rua
-rw-------   1 osni     m340            1342 Jun 21 13:27 make.inc
-rw-------   1 osni     m340            5509 Jun 21 13:27 pddrive.c
-rw-------   1 osni     m340             143 Jun 21 14:06 pddrive.err
-rw-------   1 osni     m340            6178 Jun 21 14:04 pddrive.inst.c
-rwx------   1 osni     m340             412 Jun 21 13:27 pddrive.job
-rw-------   1 osni     m340            4693 Jun 21 14:05 pddrive.o
-rw-------   1 osni     m340             394 Jun 21 14:06 pddrive.out
-rwx------   1 osni     m340          936669 Jun 21 14:05 pddrive.x
-rw-------   1 osni     m340           43904 Jun 21 13:27 pdgssvx.c
-rw-------   1 osni     m340           44428 Jun 21 14:05 pdgssvx.inst.c
-rw-------   1 osni     m340           13656 Jun 21 14:05 pdgssvx.o
-rw-------   1 osni     m340            2531 Jun 21 14:06 profile.0.0.0
                        m340            2479 Jun 21 14:06 profile.1.0.0
                        m340            2492 Jun 21 14:06 profile.2.0.0
                        m340            2501 Jun 21 14:06 profile.3.0.0
                        m340            2483 Jun 21 14:06 profile.4.0.0
                        m340            2493 Jun 21 14:06 profile.5.0.0
                        m340            2489 Jun 21 14:06 profile.6.0.0
                        m340            2487 Jun 21 14:06 profile.7.0.0
                        m340         1689384 Jun 21 14:06 tautrace.0.0.0.trc
                        m340         1436496 Jun 21 14:06 tautrace.1.0.0.trc
                        m340         1698168 Jun 21 14:06 tautrace.2.0.0.trc
                        m340         1417992 Jun 21 14:06 tautrace.3.0.0.trc
                        m340         1428456 Jun 21 14:06 tautrace.4.0.0.trc
                        m340         1696488 Jun 21 14:06 tautrace.5.0.0.trc
                        m340         1441728 Jun 21 14:06 tautrace.6.0.0.trc
                        m340         1683144 Jun 21 14:06 tautrace.7.0.0.trc
                 sni/work/pdgssvx] 
```

Makefile: *compilation rule*

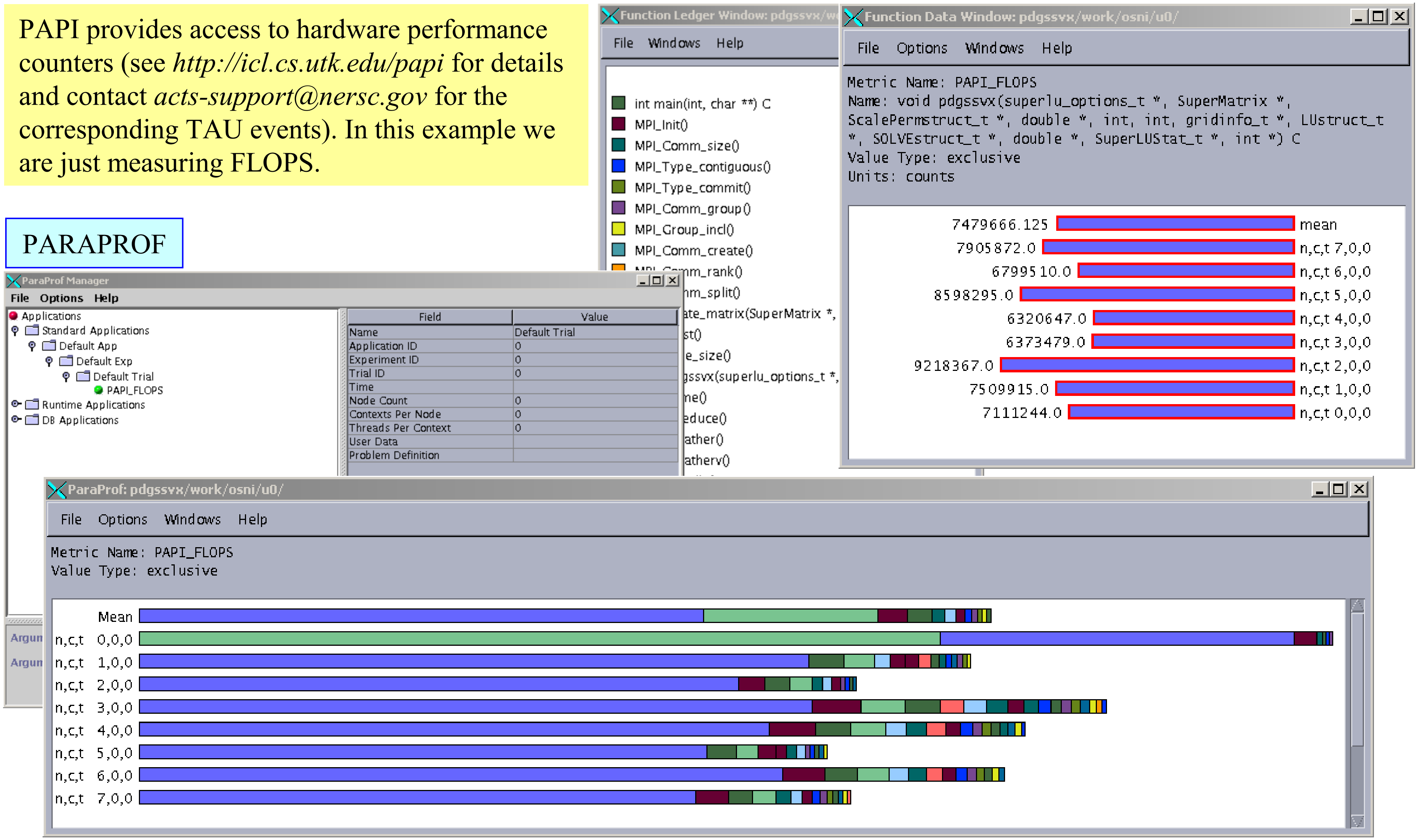
```
OBJS      = pddrive.o dcreate_matrix.o pdgssvx.o
TARGET  = pddrive.x

COMPRULE = $(PDTCPARSE) $< $(COMPFLAGS) $(CDEFS) $(INCLUDEDIR); \
           $(TAUINSTR) $*.pdb $< -o $*.inst.c -g "COMPUTATION" ; \
           $(CC) $(COMPFLAGS) $(CDEFS) $(BLASDEF) $(INCLUDEDIR) -c $*.inst.c -o $@ ; \
           rm -f $*.pdb ;

$(TARGET): $(OBJS)
           $(LINKER) $(LNKFLAGS) $(OBJS) $(LIBS) $(TAULIBS) -lm -o $@

# Compilation rule
.c.o:
           $(COMPRULE)
```

include $(TAUROOTDIR)/rs6000/lib/Makefile.tau-mpi-papi-pdt-profile-trace

TAU: *Example 2* (2/2)

PAPI provides access to hardware performance counters (see *http://icl.cs.utk.edu/papi* for details and contact *acts-support@nersc.gov* for the corresponding TAU events). In this example we are just measuring FLOPS.

PARAPROF



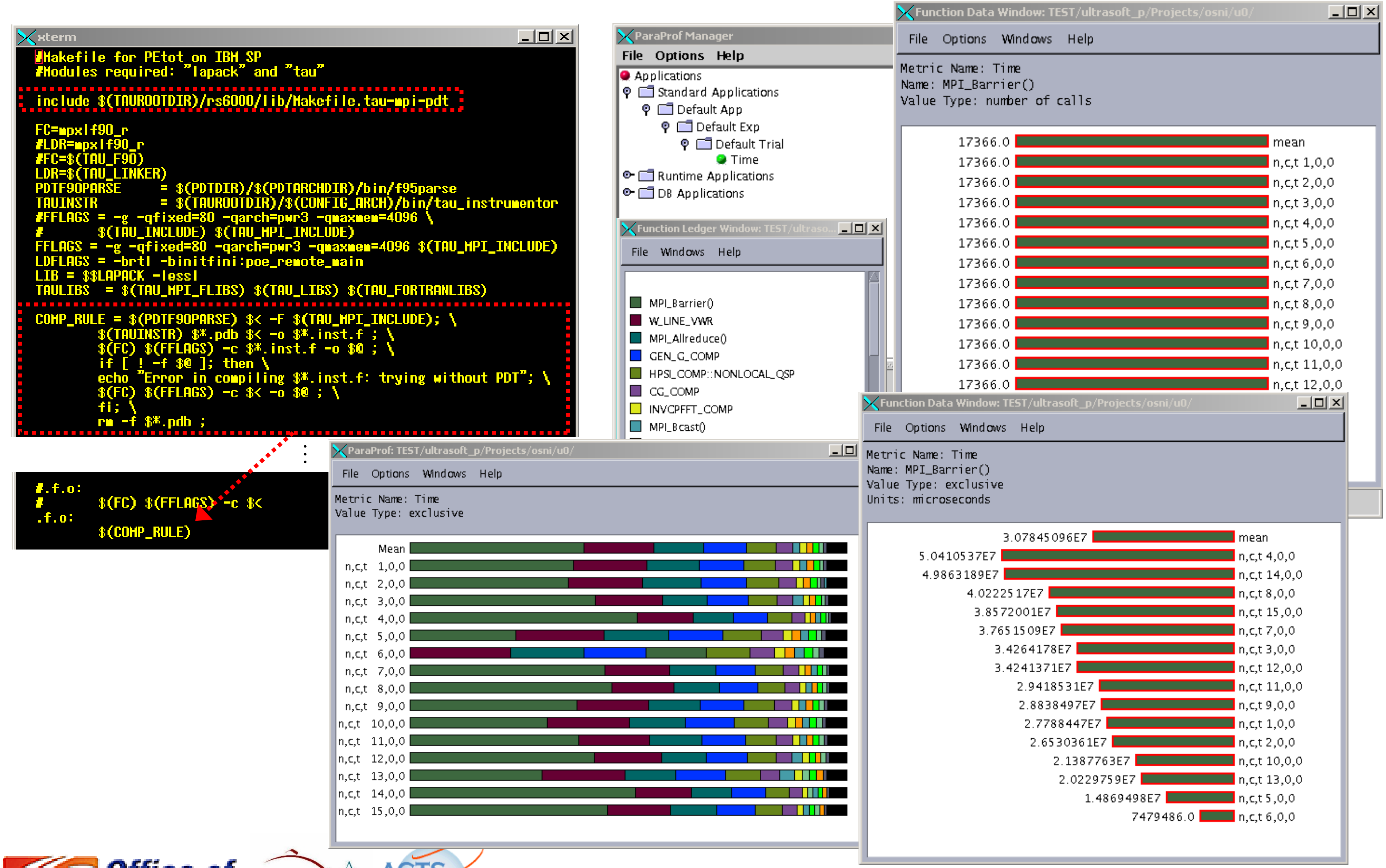
```
Metric Name: PAPI_FLOPS
Name: void pdgssvx(superlu_options_t *, SuperMatrix *,
ScalePermstruct_t *, double *, int, int, gridinfo_t *, LUstruct_t
*, SOLVEstruct_t *, double *, SuperLUStat_t *, int *) C
Value Type: exclusive
Units: counts
```

7479666.125	mean
7905872.0	n,c,t 7,0,0
6799510.0	n,c,t 6,0,0
8598295.0	n,c,t 5,0,0
6320647.0	n,c,t 4,0,0
6373479.0	n,c,t 3,0,0
9218367.0	n,c,t 2,0,0
7509915.0	n,c,t 1,0,0
7111244.0	n,c,t 0,0,0

Field	Value
Name	Default Trial
Application ID	0
Experiment ID	0
Trial ID	0
Time	
Node Count	0
Contexts Per Node	0
Threads Per Context	0
User Data	
Problem Definition	

```
Metric Name: PAPI_FLOPS
Value Type: exclusive
```

Study Case: Electronic Structure Calculations Code


xterm
ParaProf Manager
File Options Help
Function Ledger Window: TEST/ultraso...
File Windows Help
Function Data Window: TEST/ultrasoft_p/Projects/osni/u0/
File Options Windows Help
ParaProf: TEST/ultrasoft_p/Projects/osni/u0/
File Options Windows Help
Mean
n,c,t 1,0,0
n,c,t 2,0,0
n,c,t 3,0,0
n,c,t 4,0,0
n,c,t 5,0,0
n,c,t 6,0,0
n,c,t 7,0,0
n,c,t 8,0,0
n,c,t 9,0,0
n,c,t 10,0,0
n,c,t 11,0,0
n,c,t 12,0,0
n,c,t 13,0,0
n,c,t 14,0,0
n,c,t 15,0,0
Function Data Window: TEST/ultrasoft_p/Projects/osni/u0/
File Options Windows Help

```
#Makefile for PEtot on IBM SP
#Modules required: "lapack" and "tau"

 include $(TAUROOTDIR)/rs6000/lib/Makefile.tau-mpi-pdt

FC=mpxlf90_r
#LDR=mpxlf90_r
#FC=$(TAU_F90)
LDR=$(TAU_LINKER)
PDTF90PARSE     = $(PDTDIR)/$(PDTARCHDIR)/bin/f95parse
TAUINSTR        = $(TAUROOTDIR)/$(CONFIG_ARCH)/bin/tau_instrumentor
#FFLAGS = -g -qfixed=80 -qarch=pwr3 -qmaxmem=4096 \
#        $(TAU_INCLUDE) $(TAU_MPI_INCLUDE)
FFLAGS = -g -qfixed=80 -qarch=pwr3 -qmaxmem=4096 $(TAU_MPI_INCLUDE)
LDFLAGS = -brtl -binitfini:poe_remote_main
LIB = $$LAPACK -lessl
TAULIBS  = $(TAU_MPI_FLIBS) $(TAU_LIBS) $(TAU_FORTRANLIBS)

COMP_RULE = $(PDTF90PARSE) $< -F $(TAU_MPI_INCLUDE); \
        $(TAUINSTR) $*.pdb $< -o $*.inst.f ; \
        $(FC) $(FFLAGS) -c $*.inst.f -o $@ ; \
        if [ ! -f $@ ]; then \
        echo "Error in compiling $*.inst.f: trying without PDT"; \
        $(FC) $(FFLAGS) -c $< -o $@ ; \
        fi; \
        rm -f $*.pdb ;
```

⋮

```
#.f.o:
#       $(FC) $(FFLAGS) -c $<
.f.o:
        $(COMP_RULE)
```

ParaProf Manager:

- Applications
  - Standard Applications
    - Default App
      - Default Exp
        - Default Trial
          - Time
  - Runtime Applications
  - DB Applications

Function Ledger Window:

■ MPI_Barrier()
■ W_LINE_VWR
■ MPI_Allreduce()
■ GEN_G_COMP
■ HPSI_COMP::NONLOCAL_QSP
■ CG_COMP
■ INVCPFFT_COMP
■ MPI_Bcast()

```
Metric Name: Time
Value Type: exclusive
```

```
Metric Name: Time
Name: MPI_Barrier()
Value Type: number of calls
```

```
17366.0  mean
17366.0  n,c,t 1,0,0
17366.0  n,c,t 2,0,0
17366.0  n,c,t 3,0,0
17366.0  n,c,t 4,0,0
17366.0  n,c,t 5,0,0
17366.0  n,c,t 6,0,0
17366.0  n,c,t 7,0,0
17366.0  n,c,t 8,0,0
17366.0  n,c,t 9,0,0
17366.0  n,c,t 10,0,0
17366.0  n,c,t 11,0,0
17366.0  n,c,t 12,0,0
```

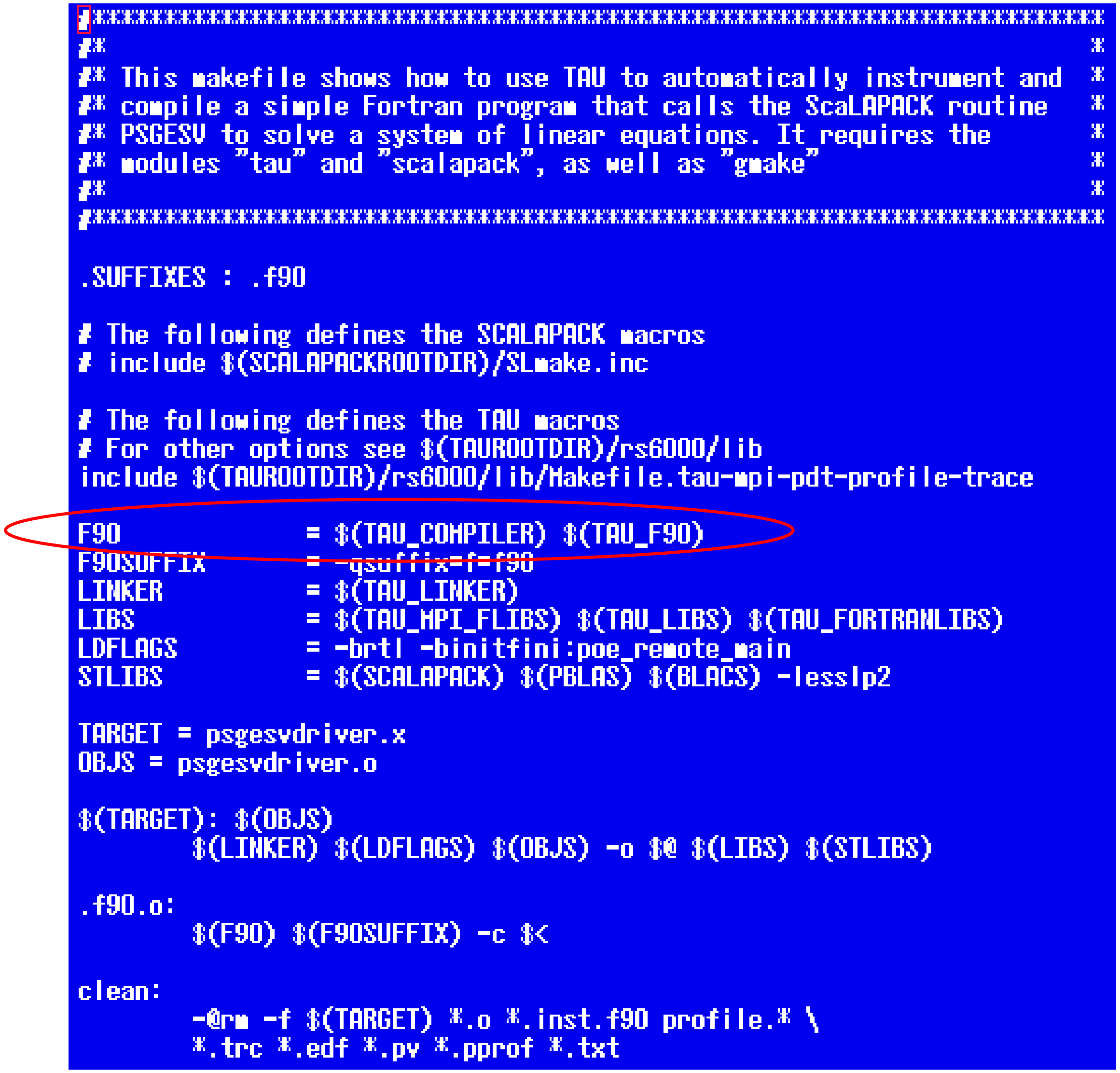
```
Metric Name: Time
Name: MPI_Barrier()
Value Type: exclusive
Units: microseconds
```

```
3.07845096E7  mean
 5.0410537E7  n,c,t 4,0,0
 4.9863189E7  n,c,t 14,0,0
 4.0222517E7  n,c,t 8,0,0
 3.8572001E7  n,c,t 15,0,0
 3.7651509E7  n,c,t 7,0,0
 3.4264178E7  n,c,t 3,0,0
 3.4241371E7  n,c,t 12,0,0
 2.9418531E7  n,c,t 11,0,0
 2.8838497E7  n,c,t 9,0,0
 2.7788447E7  n,c,t 1,0,0
 2.6530361E7  n,c,t 2,0,0
 2.1387763E7  n,c,t 10,0,0
 2.0229759E7  n,c,t 13,0,0
 1.4869498E7  n,c,t 5,0,0
   7479486.0  n,c,t 6,0,0
```

Auto Instrumentation using TAU_COMPILER

- $(TAU_COMPILER) stub Makefile variable (v2.13.7+)
- Invokes PDT parser, TAU instrumentor, compiler through **`tau_compiler.sh`** shell script
- Requires minimal changes to application Makefile
  - Compilation rules are not changed
  - User adds $(TAU_COMPILER) before compiler name
    - F90=mpxlf90
      Changes to
      F90= $(TAU_COMPILER) mpxlf90
- Passes options from TAU stub Makefile to the four compilation stages
- Uses original compilation command if an error occurs

Using TAU_COMPILER in previous example



```
#*******************************************************************************
#*                                                                             *
#* This makefile shows how to use TAU to automatically instrument and          *
#* compile a simple Fortran program that calls the ScaLAPACK routine           *
#* PSGESV to solve a system of linear equations. It requires the               *
#* modules "tau" and "scalapack", as well as "gmake"                           *
#*                                                                             *
#*******************************************************************************

.SUFFIXES : .f90

# The following defines the SCALAPACK macros
# include $(SCALAPACKROOTDIR)/SLmake.inc

# The following defines the TAU macros
# For other options see $(TAUROOTDIR)/rs6000/lib
include $(TAUROOTDIR)/rs6000/lib/Makefile.tau-mpi-pdt-profile-trace

F90             = $(TAU_COMPILER) $(TAU_F90)
F90SUFFIX       = -qsuffix=f=f90
LINKER          = $(TAU_LINKER)
LIBS            = $(TAU_MPI_FLIBS) $(TAU_LIBS) $(TAU_FORTRANLIBS)
LDFLAGS         = -brtl -binitfini:poe_remote_main
STLIBS          = $(SCALAPACK) $(PBLAS) $(BLACS) -lesslp2

TARGET = psgesvdriver.x
OBJS = psgesvdriver.o

$(TARGET): $(OBJS)
        $(LINKER) $(LDFLAGS) $(OBJS) -o $@ $(LIBS) $(STLIBS)

.f90.o:
        $(F90) $(F90SUFFIX) -c $<

clean:
        -@rm -f $(TARGET) *.o *.inst.f90 profile.* \
        *.trc *.edf *.pv *.pprof *.txt
```

TAU Performance System Status

- Computing platforms (selected)
  - IBM SP / pSeries, SGI Origin 2K/3K, Cray T3E / SV-1 / X1, HP (Compaq) SC (Tru64), Sun, Hitachi SR8000, NEC SX-5/6, Linux clusters (IA-32/64, Alpha, PPC, PA-RISC, Power, Opteron), Apple (G4/5, OS X), Windows
- Programming languages
  - C, C++, Fortran 77/90/95, HPF, Java, OpenMP, Python
- Thread libraries
  - pthreads, SGI sproc, Java,Windows, OpenMP
- Compilers (selected)
  - Intel KAI (KCC, KAP/Pro), PGI, GNU, Fujitsu, Sun, Microsoft, SGI, Cray, IBM (xlc, xlf), Compaq, NEC, Intel
- Full Tutorial by Sameer Shende

  http://acts.nersc.gov/events/Workshop2004/slides/tau.pdf